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Small craft — Watertight or quick-draining recesses and cockpits

Petits navires — Cavités et cockpits étanches ou rapidement autovideurs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see Foreword - Supplementary information.

This document was prepared by Technical Committee ISO/TC 188, *Small craft*.

This second edition cancels and replaces the first edition (ISO 11812:2001), which has been technically revised.

The main changes compared to the previous edition are as follows:

— systematic usage of the general term "recess" instead of "cockpit";

— introduction of the concept of recess open to the sea and recess with reduced risk of flooding;

— clarification of requirements;

— clarification of requirements on engine ventilation openings installed in recesses;

— implementation of multi-bottom recesses or recesses with a foot-basin in the main core of the standard;

— deletion of "major head losses" (friction in drain pipes) as their effect was very small, but this made the calculation much more complex;

— improved data for "minor head losses" (local losses) to correspond to common practice;

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Small craft — Watertight or quick-draining recesses and cockpits

1 Scope

This document specifies watertightness, draining time and sill heights requirements for watertight and quick-draining recesses and cockpits in small craft of up to 24 m load line length (see Reference [1]).

Recesses located in elevated parts of the craft are covered by this document.

This document does not specify requirements for the size, the shape and the location of recesses or cockpits. It only considers draining by gravity, and not by pumping or other methods.

It only considers normal operation of the craft, but unattended craft recess issues are out of scope.

This document does not guarantee that the water contained in a watertight or quick-draining recess or cockpit will not affect the stability and buoyancy of the craft, which are covered by ISO 12217 (all parts):2015.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8666:2016[1)], *Small craft — Principal data*

ISO 9093-1:1994[1)], *Small craft — Seacocks and through-hull fittings — Part 1: Metallic*

ISO 9093-2:2002[1)], *Small craft — Seacocks and through-hull fittings — Part 2: Non-metallic*

ISO 12216:2020, *Small craft — Windows, portlights, hatches, deadlights and doors — Strength and watertightness requirements*

ISO 12217-1:2015, *Small craft — Stability and buoyancy assessment and categorization — Part 1: Non-sailing boats of hull length greater than or equal to 6 m*

ISO 12217-2:2015, *Small craft — Stability and buoyancy assessment and categorization — Part 2: Sailing boats of hull length greater than or equal to 6 m*

ISO 12217-3:2015, *Small craft — Stability and buoyancy assessment and categorization — Part 3: Boats of hull length less than 6 m*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

1) Under revision.

3.1
design category
description of the sea and wind conditions for which a craft is assessed to be suitable

Note 1 to entry: The design categories are defined in ISO 12217 (all parts):2015.

Note 2 to entry: The definitions of design categories are in line with the European Recreational Craft Directive 2013/53/EU.

3.2
sailing craft
craft for which the primary means of propulsion is by wind power, having a reference sail area $A_S \geq 0{,}07(m_{LDC})^{2/3}$, expressed in metres squared, where m_{LDC} is the mass of the craft in the maximum load condition, expressed in kilograms

Note 1 to entry: The reference sail area, A_s, is defined in ISO 8666:2016.

3.3
non-sailing craft
craft for which the primary means of propulsion is other than by wind power, having a reference sail area $A_S < 0{,}07(m_{LDC})^{2/3}$, expressed in metres squared, where m_{LDC} is the mass of the craft in the maximum load condition, expressed in kilograms

Note 1 to entry: The reference sail area, A_s, is defined in ISO 8666:2016.

3.4
reference waterline
W_L
level of the water on the hull in the fully loaded, ready-for-use condition

Note 1 to entry: The fully loaded, ready-for-use condition is defined in ISO 8666:2016.

3.5
heeled waterline
level of the water on the hull in the fully loaded, ready-for-use condition when the craft is inclined to:

— an angle of 7° for non-sailing craft and multihulls; or

— the level of the sheer line amidships or an angle of 30°, whichever is lower, for monohull sailing craft

Note 1 to entry: The fully loaded, ready-for-use condition is defined in ISO 8666:2016.

3.6
recess
volume open to the air that can retain water within the range of loading conditions and corresponding trims

EXAMPLE Cockpits, wells, open volumes or areas bounded by bulwarks or coamings.

Note 1 to entry: Where fitted with closure device(s) according to ISO 12216:2020, cabins, shelters or lockers are not recesses.

Note 2 to entry: A recess can be composed of several recesses connected together.

Note 3 to entry: Cockpits that are open to the sea are considered as recesses. Flush decks without bulwarks or coamings are not recesses.

3.7
cockpit
recess (3.6) intended for the accommodation of people

3.8
watertight recess
recess (3.6) that satisfies the watertightness and *sill* (3.24) height requirements of this document, but not the drainage requirements

3.9
quick-draining recess
recess (3.6) with characteristics and draining capacity that satisfy all the requirements of this document for one or several design categories

Note 1 to entry: According to its characteristics, a recess can be considered as quick-draining for one design category, but not for a higher category.

Note 2 to entry: The term "quick-draining" has been chosen to differentiate from the common understanding term "self-draining", where water can be drained overboard in certain conditions, but without a specified draining speed, height of bottom or sill, etc.

3.10
recess open to the sea
recess (3.6) where the aft and/or side boundaries are open to the outside of the craft, with a *recess retention height* (3.21) equal to zero

Note 1 to entry: Figure C.1 c) gives an example of a recess open to the sea.

3.11
recess bottom
lowest surface of the *recess* (3.6), where water collects before being drained

Note 1 to entry: The recess bottom can have several levels.

3.12
recess bottom height
H_B
height of the *recess bottom* (3.11) above the waterline, the craft being upright, at rest and fully loaded

3.13
minimum recess bottom height
$H_{B\ min}$
minimum value of *the recess bottom height* (3.12) required by this document

3.14
single-bottom recess
recess (3.6) where the bottom has only one level

Note 1 to entry: A single-bottom recess fitted with a *foot basin* (3.31) is considered as a *multi-bottom recess* (3.15).

3.15
multi-bottom recess
recess (3.6) where the bottom has more than one level

3.16
bridge deck
area in the proximity of the *companionway* (3.23) opening and above the *recess bottom* (3.11), on which people normally step before entering the accommodation

3.17
interior
inside the craft's watertight envelope

3.18
watertightness degree
degree of watertightness
capacity of an *appliance* (3.20) or fitting to resist ingress of water, according to the conditions of exposure to water

Note 1 to entry: See Table 1 for a definition of the four watertightness degrees.

Table 1 — Definitions of the degrees of watertightness

Degree of watertightness:	Definition
1 (waterproof)	Constructed to withstand continuous immersion Provides protection against the effects of continuous immersion in water
2 (watertight)	Constructed to prevent ingress of water Provides protection against the effects of temporary immersion in water
3 (weathertight)	Constructed to minimize seepage Provides protection against splashing water
4 (spraytight)	Provides protection against waterdrops falling at an angle of up to 15° from the vertical
NOTE Test procedures for watertightness degrees are provided in ISO 12216:2020.	

3.19
downflooding opening
opening in the hull or deck (including the edge of a recess) that might admit water into the interior or bilge of a craft, or into a recess

Note 1 to entry: Those excluded by ISO 12217 (all parts):2015 are not considered in this document.

3.20
appliance
device used to cover an opening in the hull, deck or superstructure of a craft

EXAMPLE Windows, portlights, hatches, deadlights, doors, sliding appliances, escape hatches, washboard, compass, ventilation grids, loudspeakers, engine control panel, etc.

Note 1 to entry: They can be fixed appliances or opening appliances.

3.21
recess retention height
h_C
height of water in a *recess* (3.6), when the craft is upright and at design trim assuming that all gates, doors or drainage openings are sealed, at which the overflow area is greater than 0,005 $L_H B_H$ (m^2)

Note 1 to entry: The design trim is in maximum load condition as defined in ISO 8666:2016.

Note 2 to entry: When h_c is less than 0,10 m, it is taken as equal to 0,0 m.

3.22
drain
outlet of the *recess* (3.6) enabling water contained to be discharged overboard by gravity

EXAMPLE A pipe discharging overboard above or below waterline; a part of the recess allowing direct discharge overboard; scuppers and freeing port.

3.23
companionway
opening intended for crew access to the accommodation and fitted with an opening *appliance* (3.20)

Note 1 to entry: The opening appliance can be a door, a hatch; vertical, horizontal, etc.

Note 2 to entry: There can be several companionways.

3.24
sill
barrier above which water in the *recess* (3.6) can enter *companionway* (3.23) openings and downflood the craft

EXAMPLE Hatches of cockpit companionways.

3.25
fixed sill
sill (3.24) that is a fixed, integral and permanent part of the *recess* (3.6)

3.26
semi-fixed sill
opening *appliance* (3.20), movable but permanently installed on the craft that, when in place, constitutes a *sill* (3.24) higher than the fixed part of the sill

EXAMPLE Hatches, sliding sills, but excluding washboards.

Note 1 to entry: A lanyard is not regarded as a permanent attachment.

Note 2 to entry: Sliding or hinged doors are considered as a mobile part of a semi-fixed sill.

3.27
washboard
opening *appliance* (3.20) for *companionway* (3.23) openings made of several mobile boards sliding in a rabbet that, when closed, are stacked one on top of each other, and located above the *minimum sill height* (3.29)

Note 1 to entry: This is a frequent device on sailing monohulls; boards are added as the weather worsens.

3.28
sill height
h_S
minimum vertical distance from the top of the *sill* (3.24) to the closest part of the *recess* (3.6) bottom

Note 1 to entry: See Figure 1.

3.29
minimum sill height
$h_{S\,min}$
minimum value of the *sill height* (3.28) required by this document

3.30
recess volume
V_C
volume of water that can be contained in a *recess* (3.6) before discharge

Note 1 to entry: It is the maximum volume, considering any combination of movable coamings, etc., measured from the *recess bottom* (3.11) up to the *recess retention height* (3.21), assuming that all opening *appliances* (3.20) and *drains* (3.22) are closed.

3.31
foot basin
specific *recess* (3.6) that satisfies the requirements of 10.3 of this document, located between a recess and a *companionway* (3.23) opening, and having a lower bottom than the surrounding recess

4 Symbols

Table 2 gives the main symbols used in this document, with their meaning and unit.

Table 2 — Main symbols used in this document

Symbol	Meaning	Unit
B_H	Beam of hull as defined by ISO 8666:2016	m
F_M	Freeboard amidships as defined by ISO 8666:2016	m
h_C	Recess retention height	m
h_S	Sill height	m
$h_{S\,min}$	Minimum sill height	m
H_B	Recess bottom height above waterline	m
$H_{B\,min}$	Minimum recess bottom height above waterline	m
k_{DC}	Design category factor	—
L_H	Length of hull as defined by ISO 8666:2016	m
V_C	Recess volume	m^3
t_{max}	Maximum allowable draining time	min
t_{ref}	Reference draining time	min
d	Drain diameter	mm
NOTE Heights measured above the recess bottom have symbols beginning with h, whereas heights measured above waterline have symbols beginning with H.		

5 General

5.1 Loading and measurement conditions

Unless otherwise specifically stated in the text:

— the craft is in fully loaded, ready-for-use condition as defined in ISO 8666:2016;

— lengths and heights are measured in m, areas in m^2, volumes in m^3, time in min and/or s;

— measurements or calculations shall be made with the craft upright and at rest in calm water.

5.2 Requirements for watertight and quick-draining recesses

Table 3 summarizes the relevant clauses applicable to watertight and quick-draining recesses.

Table 3 — Relevant clauses for a recess to qualify as watertight or quick-draining

Requirements	Watertight recess	"Quick-draining" recess		
		Others	Open to the sea (3.10)	Reduced risk of flooding (7.2)
Watertightness	6.1	6.2	6.2	6.2
Companionway sill	None	Clause 7	Clause 7	None
Height of recess bottom	None	Clause 8	Clause 8	Clause 8
Drainage	None	Clause 9 or 10	None	None
Strength of appliances	ISO 12216:2020	ISO 12216:2020	ISO 12216:2020	ISO 12216:2020

6 Watertightness requirements

6.1 Watertightness requirements for watertight recesses

In watertight recesses, all surfaces and appliances shall have a degree of watertightness 1 up to a height of h_C.

6.2 Watertightness requirements for quick-draining recesses

All surfaces shall have a degree of watertightness 1.

The degree of watertightness of appliances installed in the surface of the quick-draining recess shall be as specified in Table 4.

Table 4 — Degrees of watertightness of appliances

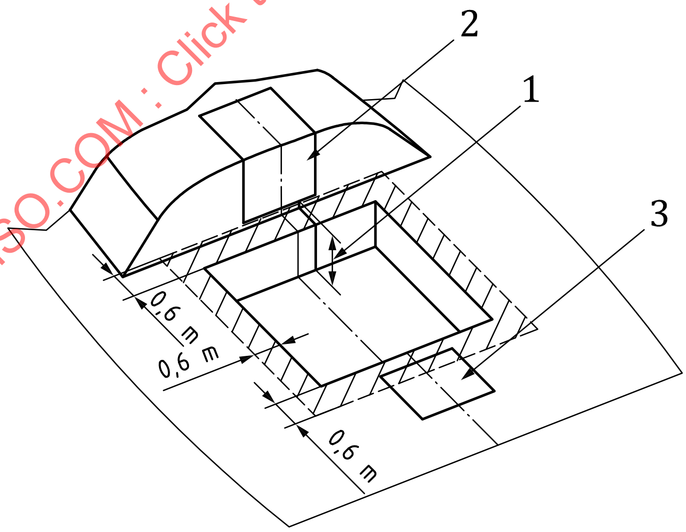
Location of appliances in the recess[a]	Degree of watertightness
appliance on bottom and sides up to $h_{S\,min}$	2
appliance between $h_{S\,min}$ and 2 $h_{S\,min}$	3
appliance above 2 $h_{S\,min}$	4
NOTE 1 On engine ventilation openings installed in a recess, a watertightness assessment can be performed using the total arrangement of exterior grid and internal ducts or swan's neck of the appliance, with material and connections sufficient to withstand the associated head of pressure.	
NOTE 2 Additional requirements can be specified in other International Standards, such as ISO 12217 (all parts):2015.	
[a] $h_{S\,min}$ is defined in Table 5, the local sill height and $h_{S\,min}$ being measured as required by 7.3	

Opening appliances covering downflooding openings and installed on the surfaces of a quick-draining recess shall be secured in the closed position by a manually operated mechanical positive device.

7 Requirements for companionway sills

7.1 Companionway sills

Any companionway inside the limits of the recess and those located within an area extending 0,6 m outside of the recess boundary shall comply with the requirements of this Clause (see Figure 1).



Key

1 sill height

2 front companionway door on bulkhead

3 aft companionway hatch on deck

Figure 1 — Sills considered and sill height measurement

7.2 Quick-draining recess with a reduced risk of flooding

A quick-draining recess with a reduced risk of flooding does not require a sill for any companionway opening if it complies with the following criteria:

— the craft is of a fully enclosed type according to ISO 12217 (all parts):2015;

— the recess is open to the sea, as defined in 3.10 of this document;

— all of the recess is located aft of the mid hull length of the craft;

— companionway(s) is(are) installed on the rear face of a superstructure;

— it has the lowest point of the companionway(s) opening higher than $[(L_h/17) + h_{S\ min}]$ above the reference waterline;

— companionway opening appliance(s) is(are) permanently installed, enabling immediate closure.

7.3 Sill height measurement

The sill height is the lowest height of the companionway, as defined in 3.28.

The sill height shall be measured vertically from the adjacent closest point of the recess bottom to the lowest point of the upper sill edge (see Figure 1).

If a multi-bottom recess is fitted with a foot basin complying with the foot basin requirements of 10.3, the sill height shall be measured from the foot basin bottom; otherwise the sill height shall be measured from the closest recess bottom

7.4 Minimum companionway sill height for quick-draining recesses

Table 5 specifies the requirements regarding minimum companionway sill height for quick-draining recesses.

These requirements do not apply to quick-draining recesses with a reduced risk of flooding.

Where a semi-fixed sill is fitted, the height of the fixed part shall be at least $(h_{S\ min}/2)$.

Table 5 — Minimum companionway sill height, $h_{S\ min}$, for quick-draining recesses

Dimensions in meters

Design category	Sailing monohulls minimum sill height, $h_{S\ min}$	Non-sailing craft and sailing multihulls minimum sill height, $h_{S\ min}$
A	0,30	0,20
B	0,25	0,15
C	0,15	0,10
D	0,05	0,05
NOTE The above requirements may be raised by other International Standards such as ISO 12217 (all parts):2015.		

8 Height of recess bottom above waterline for quick-draining recesses

Table 6 specifies the minimum recess bottom height, $H_{B\ min}$, above reference waterline, for quick-draining recesses.

For a single-bottom recess, H_B is measured at the centre of the surface of the bottom.

For a multi-bottom recess, H_B is measured at the centre of the surface of the lowest bottom.

Table 6 — Minimum height, $H_{B\ min}$, of the recess bottom above reference waterline

Dimensions in meters

Design category	$H_{B\ min}$
A	0,150
B	0,100
C	0,075
D	0,050
NOTE Greater heights than these minimum values may be required to fulfil the maximum acceptable draining time according to Clauses 9 and 10.	

9 Quick-draining recesses — Single bottom recess drainage

9.1 Drainage general requirements

Drainage shall only be by gravity.

If there are mobile parts allowing openings in the recess boundary, this requirement shall be verified in the worst configuration, e.g. if there are doors, they shall be closed.

The drainage system shall be arranged to minimize trapping of water in the recess, in both reference waterline and heeled waterline conditions.

Connected recesses with the same bottom level shall be treated as separate recesses if the sum of the areas that link them is < 120 % of the required minimum draining area of the connected recesses.

9.2 Drain requirements

9.2.1 Number and dimensions

A quick-draining recess shall have at least two drains, one port and one starboard, unless one opening enables drainage when the craft is at heeled waterline according to 9.1 to both port and starboard.

Drains with a circular cross section shall have an internal diameter of at least 25 mm.

Drains with other cross-sectional shapes shall have an internal cross-sectional area of at least 500 mm^2, and an internal minimum dimension of 20 mm.

9.2.2 Special provisions

In case of grids or systems preventing loose objects from falling into the draining system, it shall be considered that a grid with small holes is more prone to be clogged than the drain itself. The simplified drainage assessment method of 9.3.2 may be used, if

— the minimum passage dimension inside any part of these devices has at least a section of 125 mm^2 (or a diameter of 12 mm), and

— the total entry cross-section is at least 1,5 times the internal cross-section of the drain.

Otherwise the drainage assessment shall be performed according to the full calculation method of Annex A or a test method.

In case of centreboard housings and other types of aperture, these may be used as drains if:

— they are designed for this purpose, and

— they fulfil the other relevant requirements of Clause 9.

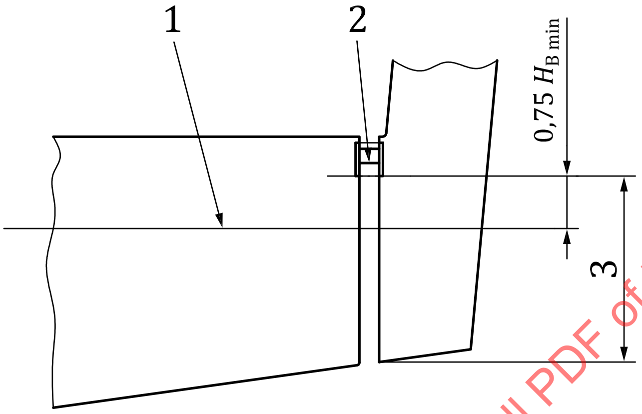
9.2.3 Installation

When the craft is in maximum load condition, the drain outlet running through the hull shall either be located:

— above the waterline, or

— below the waterline, and be fitted with seacocks unless the drain outlet is an integral part of the hull extending from the outlet up to at least 0,75 $H_{B\ min}$ above the waterline.

Figure 2 shows a drain outlet being an integral part of the hull.



Key

1 waterline

2 top of integral penetration above 0,75 $H_{B\ min}$: no seacock required

3 in this area, the drain is integral with the hull shell

Figure 2 — Drain outlet being an integral part of the hull

All the drain piping system shall have a degree of watertightness 1.

Drain piping shall be protected against damage from loose objects stowed in the craft and against being kicked or stepped on.

Drain piping installed in the engine room shall be able to withstand 70 °C or be insulated from the heat.

Drain piping shall not trap water.

Drains shall only be used for recess drainage except drains fitted in the centreboard housing or outboard wells and trunks.

Seacocks, through-hull fittings, and associated components shall comply with ISO 9093-1:1994, if metallic, and ISO 9093-2:2002, if non-metallic.

9.3 Drainage calculation requirements

9.3.1 Drainage calculation principle and assessment methods

The drainage calculation principle of this document for quick-draining recesses is based on a maximum draining time approach.

The maximum draining time, t_{max} (in min), is defined as follow:

$$t_{max} = \min\left[\frac{k_{DC} \times (L_H \times B_H \times F_M)}{V_C};5\right] \quad (1)$$

with the design category factor, k_{DC}, as defined in Table 7.

NOTE This document considers that the maximum draining time does not exceed 5 min for quick-draining recesses.

The draining time is the time elapsed to empty the recess between the retention height, h_C, and 0,1 m of the remaining water height.

The water height shall be measured above the centre of the bottom surface of the recess.

To define the size of single-bottom recess drains according to the requirements of this document for quick-draining recesses, one of the 3 following methods shall be used:

— a simplified method, as defined in 9.3.2, which provides conservative results;

— an full calculation method, as defined in Annex A, which gives more accurate results;

— a test method, in accordance with a maximum draining time, t_{max}.

The draining time shall be assessed, by test or by calculation, with every opening appliance closed.

If the draining section of the recess is greater than or equal to 0,05 V_C, this recess does not require a draining time assessment.

9.3.2 Simplified drainage assessment method

The following calculation method is applicable to single level bottom recesses.

Step 1 – Determine the recess volume, V_C (m^3).

Step 2 – Determine the design category factor, k_{DC}, using Table 7.

Table 7 — Design category factor, k_{DC}, of quick-draining recesses

Design category	k_{DC}
A	0,30
B	0,45
C	0,60
D	0,90

Step 3 – Calculate the required reference draining time t_{ref} (min):

$$t_{ref} = \min\left[\frac{k_{DC} \times (L_H \times B_H \times F_M)}{V_C};5\right] / V_C \quad (2)$$

NOTE This document considers that the maximum draining time does not exceed 5 min for quick-draining recesses.

Step 4 – Determine the required diameter, d (mm), of the pair of circular drains

With Table 8, by interpolation if necessary, determine the d value from the required value of t_{ref}

According to 9.2.1, the value of d shall not be taken less than 25 mm.

For other drain arrangements than those in Table 8, one of the 2 other methods from 9.3.1 shall be used.

Table 8 — Drain diameter, d, as a function of t_{ref} and typical drain arrangements

Typical drain arrangement	Value of t_{ref} (min)																		
Case 1 [a]	10,5	7,3	5,4	4,1	3,2	2,6	2,2	1,8	1,6	1,3	1,2	1,0	0,8	0,7	0,5	0,5	0,4	0,3	0,3
Case 2 [b]	7,6	5,3	3,9	3,0	2,4	1,9	1,6	1,3	1,1	1,0	0,8	0,7	0,6	0,5	0,4	0,3	0,3	0,2	0,2
Diameter *d* (mm)	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**

[a] Typical drain arrangement "Case 1": 2 freeing ports, above waterline, no flap.

[b] Typical drain arrangement "Case 2": 2 drain outlets, above waterline, no elbow, smooth drain entry and no grid.

NOTE 1 Considering main parameters in calculations, these two typical arrangements are the most conservative.

NOTE 2 Case 2 with outlets below waterline is less conservative than Case 2 itself.

10 Quick-draining recesses — Multi-bottom recess drainage

10.1 Drainage general requirements

Multi-bottom recesses shall have a drainage system complying with the requirements of 9.1 and 9.2.

The draining time shall be either tested or assessed by calculation according to the method of 10.2.

When a multi-bottom recess is fitted with a foot-basin, it shall also comply with 10.3.

10.2 Drainage calculations

This subclause provides the step by step method to calculate the draining time of multi-bottom recess.

Step 1 – Calculate the total volume, V_C, of the multi-bottom recess.

Step 2 – Calculate t_{max} related to V_C using Formula (1).

Step 3 – Calculate the time t_{ref1} to drain the volume V_1 from h_C to the highest bottom level.

Step 4 – Define the sub-volumes V_n to drain for each remaining drainage system.

Step 5 – Calculate the draining times t_{refn} of each sub-volume V_n (see Formulas in Clause A.3).

Where one of these sub-volumes V_n is open to the sea, no drainage calculation is required and t_{refn} = 0.

Step 6 – Calculate the sum of t_{refn}; when considering multiple sub-volumes draining at the same time, the longest draining time obtained shall be used in the draining time sum.

The maximum time elapsed to empty a multi-bottom recess from the retention height h_C to a level of 0,1 m of remaining water height shall be less than t_{max} calculated in step 1 of this process.

The remaining water height shall be calculated in the last sub-volume to drain.

Figure 3 provides an example of assessment for a multi-bottom level recess arrangement, where:

a) the volume Vc is split into sub-volumes V_1, V_2, V_3, V_4 and V_5 according to the respective bottom levels;

b) t_{ref1}, t_{ref2}, t_{ref3}, t_{ref4}, and t_{ref5} are the draining time of the respective sub-volumes V_1, V_2, V_3, V_4 and V_5;

c) the longest draining time sum from [t_{ref1}+t_{ref2}+t_{ref3}] or [t_{ref1}+t_{ref4}+t_{ref5}] shall be less than t_{max}.

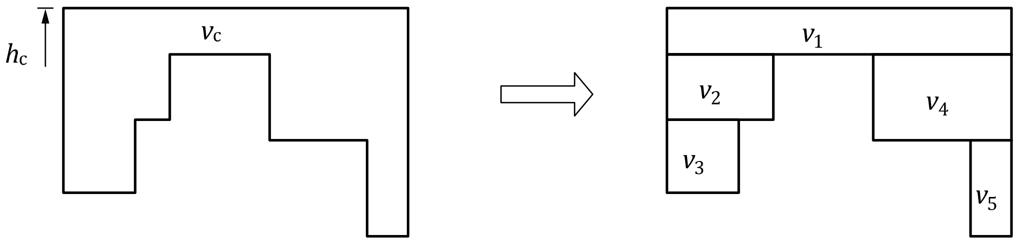


Figure 3 — Example of multi-bottom recess arrangement assessment

10.3 Drainage requirements for a foot basin

A foot basin is intended to reduce the sill height relative to the recess bottom. These additional requirements are intended to minimize ingress by ensuring the water drains quickly before reaching the level of the sill.

The foot basin shall drain a volume of not less than $h_{\mathrm{S\,min}}$ × multi-bottom recess total area.

In addition to the requirements of 10.1 and 10.2, as a specific recess of a multi-bottom recess, a foot basin shall comply with the requirements of Table 9.

Table 9 — Requirements for a foot basin

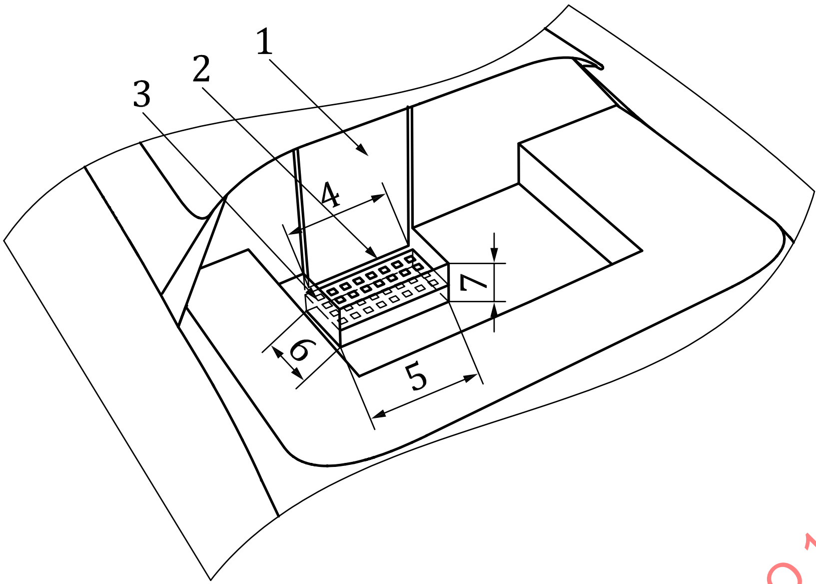
Characteristics of the foot basin[a]	Requirements
Minimum width	≥ 90 % of the maximum width of companionway opening
Length[b]	The length of the upper part of the foot basin (normal to the companionway width) shall be: between 2 × $h_{\mathrm{S\,min}}$ and 4 × $h_{\mathrm{S\,min}}$
Minimum depth[c]	The depth (below upper level of the adjacent recess bottom) shall not be less than: 1 × $h_{\mathrm{S\,min}}$
Minimum volume[d]	The volume shall be at least: $3h_{\mathrm{S\,min}}^2 \times width$
Location	Immediately in way of companionway opening(s), see Figure 4
Grating permeability	The grating permeability shall be: equally spread on the total area of the grating, ≥ 25 % or a specific draining time calculation is made considering the minor head losses at grating level according to A.5.2[b]
Sill height measurement	The sill height shall be measured from the bottom of the foot basin
Companionway door	Companionway opening appliance(s) shall be permanently installed, enabling immediate closure

[a] If the total drainage area is >25 % of the foot basin bottom area, a device protecting water surging from below shall be provided.

[b] This requirement prevents the water rebounding on the grating and flooding inside the interior.

[c] The length and the width of the foot basin is measured at the minimum depth required $h_{\mathrm{S\,min}}$.

[d] To calculate the volume of the foot basin, the depth used is the lowest of the actual depth and the actual sill height.



Key

1 companionway opening
2 actual sill above foot basin bottom or above recess bottom
3 grating
4 width of companionway opening
5 width of foot basin
6 length of foot-basin parallel to hull length
7 depth of foot-basin below adjacent recess bottom

Figure 4 — Main dimensions of a foot basin

The maximum draining time shall comply with the requirements specified in Table 10, assessed for drainage until 0,10 m remaining height of water on its bottom.

Table 10 — Drainage of a recess fitted with a foot basin

Time in minutes

Recess type	Maximum draining time
Normal	0,5 t_{max}
Open to the sea	0,2 t_{max}

11 Owner's manual

11.1 General recommendation for use

The owner's manual shall recommend keeping the drain system clear of debris or ropes, and checking seacock operation, where relevant.

Opening appliances covering downflooding openings and installed on the surfaces of a quick-draining or watertight recess shall be identified in the owner's manual, and special provisions shall instruct the users to secure them in the closed position while underway.

11.2 Recommendation for use from Table 4 — Companionway opening

The owner's manual shall state that:

— all opening appliances in the recesses shall be closed at sea, only companionway appliances (i.e. door and its eventual horizontal sliding part) are opened to allow passage when entering and leaving the interior;

— semi-fixed sills, including washboards, shall be raised in the closed position.

NOTE The companionway and its location can, if relevant, be specified by a text or a sketch.

Annex A
(normative)

Full calculation method for draining time

A.1 Preliminary

An explanation of the source of the Formulas of this Annex can be found in Annex B.

A.2 Calculation of a single-bottom recess

1) Determine the recess volume coefficient, $k_C = \dfrac{V_C}{L_H \times B_H \times F_M}$

   and $t_{max} = \min\left[\dfrac{k_{DC} \times (L_H \times B_H \times F_M)}{V_C};5\right]$,

   with design category factor k_{DC} defined in Table 7.

2) From the arrangement of the drain system, use Figure A.1 to select the relevant drain arrangement:

   — Arrangement 1.n, for freeing port, drain above W_L, no drain piping.

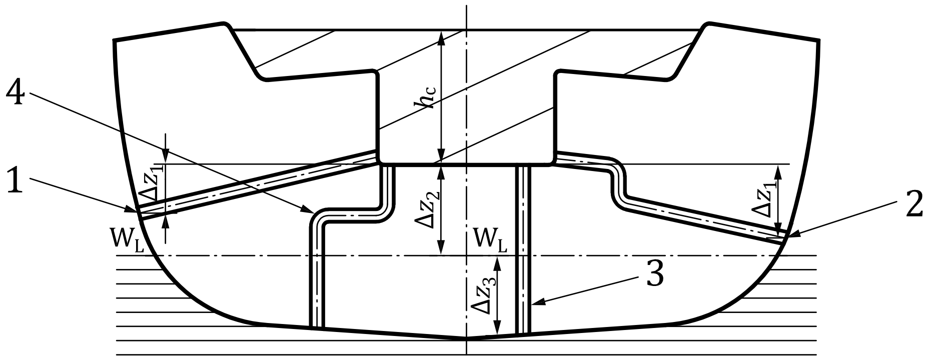
   — Arrangement 2.n, for drain with piping ending above W_L; where n = 1 for no elbow, n = 2 for 2 elbows.

   — Arrangement 3.n, for drain with piping ending below W_L; where n = 1 for no elbow, n = 2 for 2 elbows.

   If the drain arrangement is different from the ones in this Annex, the formulas of Annex B shall be used, the sum of minor head losses being taken from the values given in A.6.

3) Use Tables A.1 and A.2 for the values of minor head losses. $\sum K = K$ entry + K internal (elbows) + K outlet. Where other type of entry (e.g. grid of holes, grating) or elbows are used, the values shall be taken from Clause A.5 or from documented data. If the drain outlet is above the waterline when the recess is empty, and below the waterline when the recess is full, either consider the drain always below waterline, or make the calculation in both cases and calculate the final time by interpolation.

4) Calculate the required drain diameter using the relevant formulas of this Annex.



Key

1 drain outlet above W_L without elbow (drain case 2.1 see Table A.1)
2 drain outlet above W_L with two elbows (drain case 2.2 see Table A.1)
3 drain outlet below W_L without elbow (drain case 3.1 see Table A.1)
4 drain outlet below W_L with two elbows (drain case 3.2 see Table A.1)

Figure A.1 — Drain arrangements of Table A.1

Table A.1 — Parameters of the drain system

Drain case	Type of arrangement	h_c m	Δz_1 m	Δz_2 m	Δz_3 m	$\sum K$ total
1.n[a]	Freeing port (above W_L)	h_c	none	none	none	K
2.n[a]	Drain outlet above W_L	hc	$\Delta z1$	none	none	$\sum K$
3.n[a]	Drain outlet below W_L	h_c	none	Δz_2	Δz_3	$\sum K$

[a] Values of n are n = 1 for no elbow (or flap for freeing port), n = 2 for 2 elbows (or flap for freeing port)

Table A.2 — Values of typical minor losses for the main arrangements of Figure A.1 and Table A.1

Drain case	Type of arrangement	K entry	$\sum K$ intern	K out-let	$\sum K$ total
1.1	Freeing port above W_L, no flap	0,40	0	0	0,40
2.1	Drain outlet above W_L, no elbow, drain inlet rounded	0,36	0	0	0,36
2.2	Drain outlet above W_L, 2 about 90° round elbows r = 2d, drain inlet rounded	0,36	0,35	0	0,71
3.1	Drain outlet below W_L, no elbow, drain inlet rounded	0,36	0	1	1,36
3.2	Drain outlet below W_L, 2 about 90° round elbows r = 2d, drain inlet rounded	0,36	0,35	1	1,71

K and $\sum K$ summarized in drain cases 1.1 to 3.2 correspond to the most typical cases.

Table A.3 — Calculation of the draining time, t_{max}, according to d for single-bottom recesses

Type of arrangement	Draining time t_{max} (min) for partial drainage according to d (mm) or required drain diameter d (mm) according to t_{max} (min) two drains, each one diameter d
Drain case 1 Freeing port (above W_L)	$t_{p1}=\sqrt{1+\Sigma K}\times\frac{4791}{d^2}\times\frac{V_c}{h_c}\times\left(\sqrt{h_c}-\sqrt{0,1}\right)$ $d_{p1}=\sqrt{\sqrt{1+\Sigma K}\times\frac{4791}{t_{max}}\times\frac{V_c}{h_c}\times\left(\sqrt{h_c}-\sqrt{0,1}\right)}$

Subscript p for draining time t and drain diameter d means that the calculation is for partial drainage (subscript f is for full).

Table A.3 *(continued)*

Type of arrangement	Draining time t_{max} (min) for partial drainage according to d (mm) or required drain diameter d (mm) according to t_{max} (min) two drains, each one diameter d
Drain case 2 Drain outlet above W_L	$t_{p2} = \sqrt{1+\Sigma K} \times \frac{4791}{d^2} \times \frac{V_c}{h_c} \times \left(\sqrt{h_c + \Delta z_1} - \sqrt{0{,}1 + \Delta z_1}\right)$ $d_{p2} = \sqrt{\sqrt{1+\Sigma K} \times \frac{4791}{t_{max}} \times \frac{V_c}{h_c} \times \left(\sqrt{h_c + \Delta z_1} - \sqrt{0{,}1 + \Delta z_1}\right)}$
Drain case 3 Drain outlet below W_L	$t_{p3} = \sqrt{1+\Sigma K} \times \frac{4791}{d^2} \times \frac{V_c}{h_c} \times \left(\sqrt{h_c + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{0{,}1 + \Delta z_2 + 0{,}9\Delta z_3}\right)$ $d_{p3} = \sqrt{\sqrt{1+\Sigma K} \times \frac{4791}{t_{max}} \times \frac{V_c}{h_c} \times \left(\sqrt{h_c + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{0{,}1 + \Delta z_2 + 0{,}9\Delta z_3}\right)}$
Variables (see Figure A.1)	t_{max} time for partial drainage (0,1 m remaining) (min) d drain diameter (mm) calculation for 2 drains $\sum K$ sum of minor head losses (1) From Table A.2 or Annex B h_c recess retention height (m) V_c recess/cockpit volume (m^3) Δz_1 height of recess bottom above drain outlet (m) for drain outlet above W_L Δz_2 height of recess bottom above W_L (m) for drain outlet above W_L Δz_3 height of drain outlet below W_L (m) for drain outlet below W_L
Subscript p for draining time *t* and drain diameter *d* means that the calculation is for partial drainage (subscript f is for full).	

A.3 Calculation for a multi-bottom recess

Clause 10.2 provides the process to be followed for this assessment.

Calculations shall be made according to the formulas of Table A.3 where this document considers the upper sub-volume $V_1 = S_1 \times (h_c - h_i)$ and the lower sub-volume $V_2 = S_2 \times (h_i - 0{,}1)$, with S_1 and S_2 the bottom surface of respective sub-volumes V_1 and V_2.

CAUTION — h_c is the total height from lower level bottom to top of water retention height in the upper level, and not the water retention in the upper sub-recess (h_c-h_i), see Figure A.2.

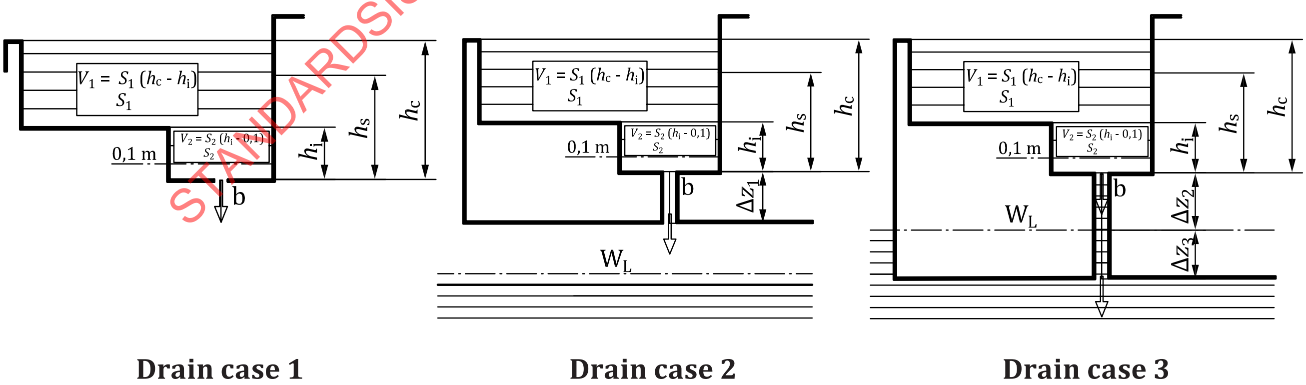


Figure A.2 — Closed recess with two levels with 3 types of drain arrangement

Table A.4 — Formulas for calculation of the draining time t_{max} or minimum drain diameter d for double bottom recess

Type of arrang.	**Draining time** t (min) **for partial drainage according to** d (mm), **two drains, each one diameter** d
Drain case 1 Freeing port (above W_L)	$$t_1 = \left(\sqrt{1+\Sigma \mathrm{K}} \times \frac{4791}{d_1^2}\right) \times \left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c} - \sqrt{h_i}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i} - \sqrt{0{,}1}\right)\right]$$ $$d_1 = \sqrt{\left(\sqrt{1+\Sigma K} \times \frac{4791}{t_1}\right) \times \left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c} - \sqrt{h_i}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i} - \sqrt{0{,}1}\right)\right]}$$
Drain case 2 Drain outlet above W_L	$$t_2 = \left(\sqrt{1+\Sigma K} \times \frac{4791}{d_2^2}\right) \times \left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c + \Delta z_1} - \sqrt{h_i + \Delta z_1}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i} - \sqrt{0{,}1}\right)\right]$$ $$d_2 = \sqrt{\left(\sqrt{1+\Sigma K} \times \frac{4791}{t_2}\right) \times \left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c + \Delta z_1} - \sqrt{h_i + \Delta z_1}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i} - \sqrt{0{,}1}\right)\right]}$$
Drain case 3 Drain outlet below W_L	$$t_3 = \sqrt{1+\Sigma K} \times \frac{4791}{d_3^2} \times$$ $$\left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{h_i + \Delta z_2 + 0{,}9\Delta z_3}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{0{,}1 + \Delta z_2 + 0{,}9\Delta z_3}\right)\right]$$ $$d_3 =$$ $$\sqrt{\sqrt{1+\Sigma K} \times \frac{4791}{t_3} \times \left[\frac{V_1}{(h_c - h_i)}\left(\sqrt{h_c + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{h_i + \Delta z_2 + 0{,}9\Delta z_3}\right) + \frac{V_2}{h_i}\left(\sqrt{h_i + \Delta z_2 + 0{,}9\Delta z_3} - \sqrt{0{,}1 + \Delta z_2 + 0{,}9\Delta z_3}\right)\right]}$$
Variables (See Figure A.2)	t time (min) for partial drainage (0,1 m remaining) d drain diameter (mm) calculation for 2 drains ΣK sum of minor hear losses (1) From A.2 or Annex B V_1 volume of upper recess/cockpit (m^3) h_c total recess retention height (m) V_2 volume of lower recess/cockpit (m^3) h_i intermediate recess retention height (m) Δz_1 height of recess bottom above drain outlet (m) for drain outlet above W_L Δz_2 height of recess bottom above W_L (m) for drain outlet above W_L Δz_3 height of drain outlet below W_L (m) for drain outlet below W_L
NOTE The above Formulae can be inverted to find d according to t, but it is probably simpler to apply the above Formulae changing the value of d until t is equal to the required value.	

A.4 Principle of calculation where the drain diameters are different

If the two drains or more have different diameters, the draining time assessment can be complex as the water flows in each drain are different. The basics of Annex B shall be used.

A.5 Determination of minor head loss coefficients, K

A.5.1 General

Seacocks are considered fully open and are therefore not considered as a specific head loss cause.

In general, each draining system of a recess has a minor loss at the entry and at the outlet, plus eventual intermediate minor losses due to elbows / changes of direction, or sudden change of section.

This document only considers the main cases. Typical values of additional head losses are listed in this clause. Where relevant, other documented sources may be used.

For more precise assessments of K, any existing documented data may be used instead of the above approximations.

Where the section is not circular, an equivalent diameter shall be used.

Table A.5 — Calculated or default values of K for various discontinuities

	Type of fitting	Discontinuity	Formula or data	$c_q = \sqrt{1+K}$
Entry of drain piping system	Entry with sharp angles	Sudden contraction	$K = (1 + S_1 / S_E)^2$ [b]	1,23
	Entry with chamfered angle			1,12
	Entry with rounded angles		See Table A.7	1,06
	Grid of round holes or grating		See Table A.10	1,73
Outlet of piping system	Outlet discharge above W_L	Sudden expansion	0	0,00
	Outlet discharge below W_L		$= (1 + S_1 / \infty)^2$	1,00
Flow changes inside drain system	Round elbow	Flow change	See Table A.8 or A.9	1,17
	Sharp elbow		See Table A.10	1,46
	Sudden expansion		$K = (1 + S_2 / S_1)^2$	
	Sudden contraction		$K = (1 + S_1 / S_E)^2$	

[a] A freeing port is an aperture in the wall of the recess with no drain piping, see Figure 5. It can be fitted with a flap preventing water to enter back but slowing the flow.

[b] In case of sudden contraction (drain entry and change in diameter), the flow contracts into a section S_E usually 0,75 times the actual section S_2.

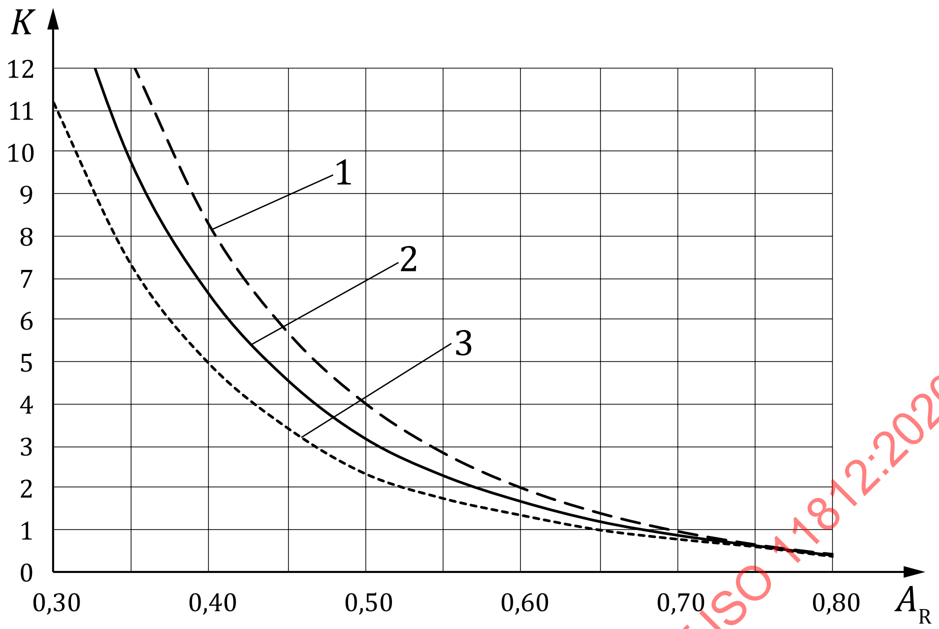
A.5.2 K coefficient for grid of holes and gratings

This subclause provides values and formulas to define the K coefficient in case of gratings and grids of holes.

Table A.6 — Values of K for different types of grids according to the area ratio, A_R

A_R [a]	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80
Grid of holes	18,6	12,2	8,3	5,7	4,0	2,8	2,0	1,4	1,0	0,7	0,4
Parallel bars	14,9	9,8	6,6	4,6	3,2	2,3	1,7	1,2	0,9	0,6	0,4
Square grating	11,2	7,3	5,0	3,4	2,3	1,8	1,4	1,0	0,8	0,6	0,4

[a] Aspect ratio $A_R = a/a_0$ where a is the passage slot and a_0 reflects spacing between slots.



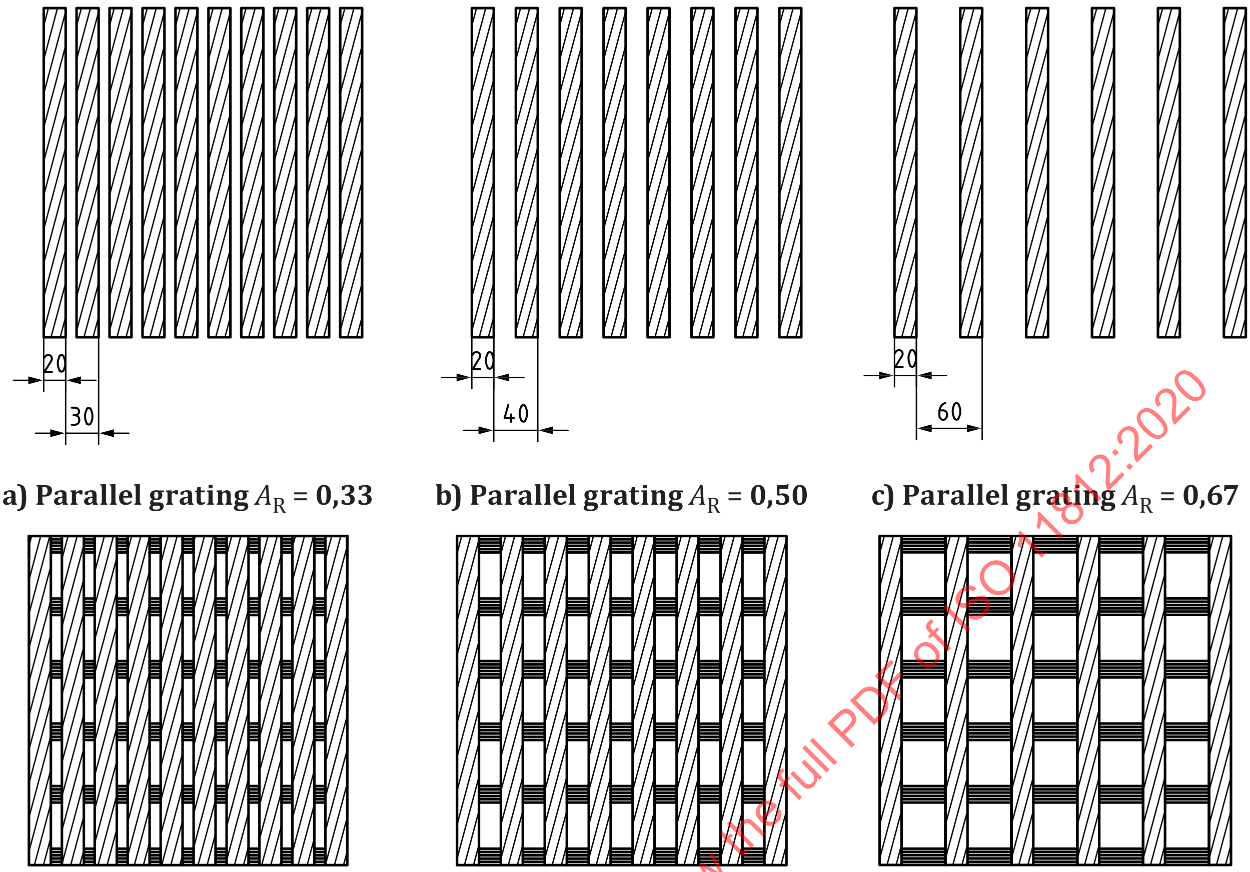
Key

1 grid of round holes

2 square grating

3 parallel grating

Figure A.3 — Values of *K* for different kinds of grids according to the area ration, A_R



a) Parallel grating A_R = 0,33 b) Parallel grating A_R = 0,50 c) Parallel grating A_R = 0,67

d) Square grating A_R = 0,26 e) Square grating A_R = 0,33 f) Square grating A_R = 0,44

Figure A.4 — Examples of square and parallel gratings

A.5.3 *K* coefficient for drains

Tables A.7 to A.10 provide values to define the *K* coefficient for typical drain fittings.

Table A.7 — Values of $K_{m\ inlet}$ for a drain entry with rounded edge

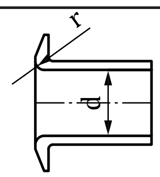
r/d	0,00	0,01	0,02	0,06	0,08	0,10	0,16	≥0,20	
K	0,50	0,43	0,36	0,31	0,15	0,12	0,06	0,03	

Table A.8 — Values of *K* for a 90°rounded elbow

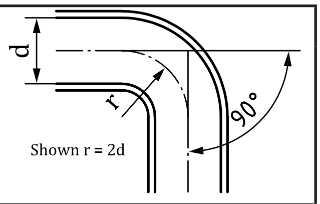
r/d	2	3	4	5	6	7	
K	0,30	0,26	0,23	0,20	0,18	0,17	

Table A.9 — Values of *K* for a rounded elbow with radius *r*/*d*=2

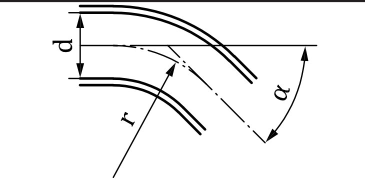
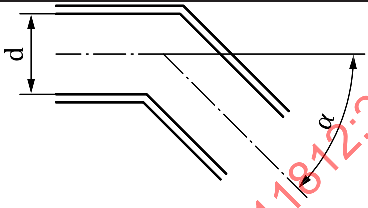
α	15°	30°	45°	60°	90°	
K	0,06	0,12	0,18	0,24	0,30	

Table A.10 — Values of *K* for an angled elbow

α	15°	30°	45°	60°	90°	
K	0,06	0,17	0,32	0,68	1,26	

Annex B
(informative)

Technical background — Source of the calculations used

B.1 Calculations for a single-bottom recess

B.1.1 General

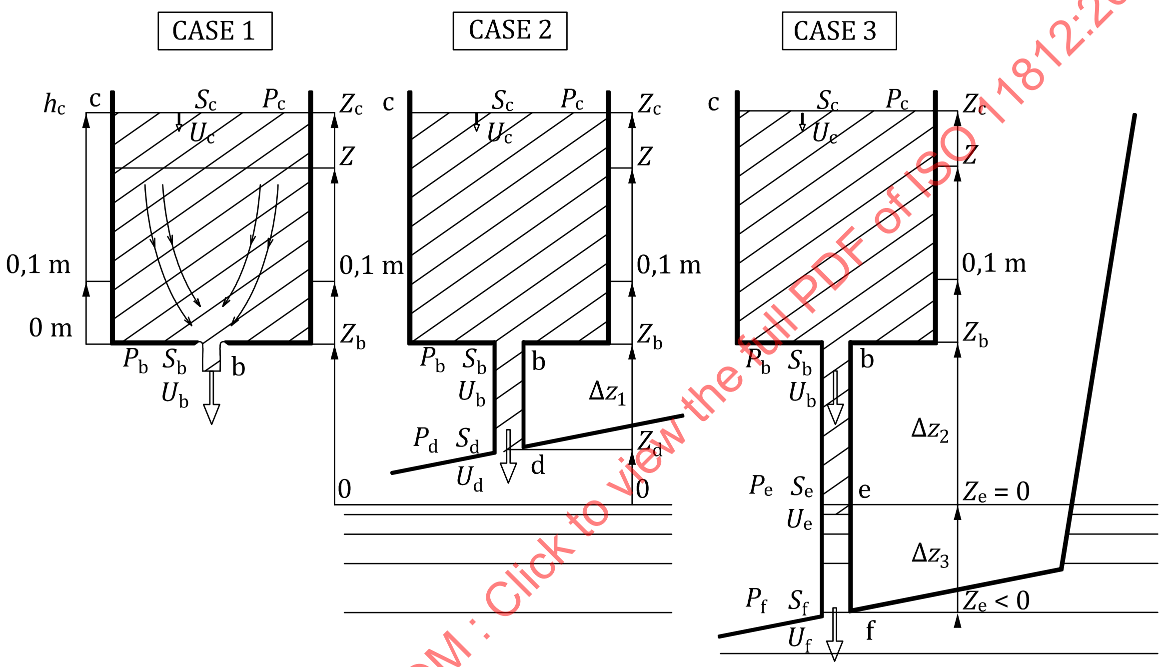


Figure B.1 — Various types of drain in a single-bottom recess

The above drawing shows a recess with contained water height $h_c = z_{c-} z_b$

1) a direct drain (freeing port) at recess bottom and above waterline;

2) a drain with a pipe with a vertical height $z_b - z_d = \Delta z_1$ but still ending above waterline;

3) a drain with a pipe ending below waterline with a total vertical height $z_b - z_f = \Delta z_2 + \Delta z_3$ with $z_b - z_e = \Delta z_2$ with point “e” at W_L and $z_e - z_f = \Delta z_3$ with point “f” below W_L.

Table B.1 — Used variables

Variable	Unit	Definition
u	m/s	Flow speed of the water
g	m/s^2	Acceleration of gravity = 9,81 m/s^2
h	m	Height of water in the recess (h_c when full) above recess bottom
p	pa	Pressure
z	m	height of water in the recess above waterline
d	mm	drain diameter (two drains are assumed)
D	m	drain diameter (two drains are assumed)

Table B.1 *(continued)*

Variable	Unit	Definition
V_C	m^3	Recess volume
ρ	kg/m^3	Sea water density (ρ = 1 025 kg/m^3)

B.1.2 Calculation for a "perfect" fluid, i.e. no viscosity and no head loss

The Bernoulli equation for "perfect" fluids can be applied between two points: point 1 (at the top of water in the recess) and point 2 (at the outlet) on the same line of flow (without head loss and without energy input/output):

$\frac{u_1^2}{2}+\frac{p_1}{\rho}+gz_1=\frac{u_2^2}{2}+\frac{p_2}{\rho}+gz_2$ and therefore

$u_2=\sqrt{2\times\left(\frac{p_1-p_2}{\rho}+g\left(z_1-z_2\right)+\frac{u_1^2}{2}\right)}$ and as the section of the recess is very large, u_1 is small and $\frac{u_1^2}{2}\approx 0$.

$u_2=\sqrt{2\times\left(\frac{p_1-p_2}{\rho}+g\left(z_1-z_2\right)\right)}$ = $u_2=1{,}414\sqrt{\left(\frac{p_1-p_2}{\rho}+g\left(z_1-z_2\right)\right)}$

and in the case of a drain outlet above waterline where $p_1 = p_2$, $u_2=4{,}43\sqrt{z_1-z_2}$

In cases 1 and 2, the applied pressure is the same: the atmospheric pressure.

The atmospheric pressure is p_{atm} = 1,013 × 10^5 Pa = 0,101 3 MPa = 10,13 m fresh water head, or 9,88 salt water head with a sea water density ρ = 1 025 kg/m^3 and p_{atm}/ρ = 98,92.

In case 3 the pressure at the outlet is greater and $p_f=p_{atm}+\rho\Delta z_3$ in Pa.

DRAIN CASE 1 — Drain opening at the bottom of the recess, no pipe

The Bernoulli equation applied at a point z between point c (top of water retention) and point b (recess bottom) is $\frac{u^2}{2}+gz=\frac{u_b^2}{2}+gz_b$. The pressure disappears as it is the same atmospheric pressure on both sides. As the water is incompressible, the flow is the same at points c and b: $S\times u=S_b\times u_b$, hence the formula of flows can also be written: $u_b\times S_b\times dt=S\times -dz$ or $dt=-\frac{S_a\times dz}{S_b\times u_b}$

Replacing u_b by its value $u_b=\sqrt{2gz}$ then $dt=-\frac{S_a}{S_b\times\sqrt{2g}}\times\frac{dz}{\sqrt{z}}$ (sign – as z diminishes with t). Time to fully drain, is the integration $t=-\frac{S_a}{S_b\times\sqrt{2g}}\int_{z_c}^{z_b}\frac{dz}{\sqrt{z}}$ between z_c and z_b, and as the primitive of $\frac{1}{\sqrt{z}}$ is $2\sqrt{z}$.

Choosing h as the variable instead of z (0 at bottom b and h_c at top) $t=-\frac{S_a}{S_b\times\sqrt{2g}}\times 2\left(\sqrt{h_c}-\sqrt{0}\right)$ and as $S_a=\frac{V_C}{h_c}$, with V_c recess volume and the drain section at point b $S_b=\frac{2\times\pi\times D^2}{4}$ for 2 drains diameter D (m)

Then $t=-\frac{1}{\sqrt{2g}}\frac{V_C}{h_c}\times\frac{2}{\pi\times D^2}2\sqrt{h_c}$ and using d (mm) and t (min) $\frac{4}{60\times\pi\times 10^{-6}\sqrt{2g}}=4791$, knowing that $\frac{\sqrt{h_c}}{h_c}=\frac{1}{\sqrt{h_c}}$ finally gives $t_f=\frac{4791}{d^2}\times\frac{V_C}{\sqrt{h_c}}$ time for full drainage (subscript f).

If the height at the bottom is ≠ 0, partial drainage (subscript p) requires integration between h_c and 0,10

$t_{\mathrm{p}} = \frac{4791}{d^2} \times \frac{V_C}{h_c}\left(\sqrt{z_c} - \sqrt{0,1}\right)$ and, to sum up:

Drain case 1 full drain, no head loss $t_{\mathrm{f1}} = \frac{4791}{d^2} \times \frac{V_{\mathrm{C}}}{\sqrt{h_{\mathrm{c}}}}$

Partial drain, no head loss $t_{\mathrm{p}} = \frac{4791}{d^2} \times \frac{V_C}{h_c}\left(\sqrt{h_c} - \sqrt{0,1}\right)$

DRAIN CASE 2 — Drainage with a vertical pipe ending above waterline

The Bernoulli equation is applied at point z (between points c and b) and outlet point d, which is lower than b but still at the atmospheric pressure. $\frac{u^2}{2} + gz = \frac{u_{\mathrm{d}}^2}{2} + gz_{\mathrm{d}}$ and $u \approx 0$, then $u_{\mathrm{d}} = \sqrt{2g\left(z - z_{\mathrm{d}}\right)}$ and

$t_{\mathrm{f}} = \frac{4791}{d^2} \times \frac{V_{\mathrm{C}}}{h_{\mathrm{c}}} \int_{z_{\mathrm{c}}}^{z_{\mathrm{b}}} \frac{\mathrm{d}z}{\sqrt{z - z_{\mathrm{d}}}}$ with z_{d} = constant and as the primitive of $\frac{1}{\sqrt{z + \text{constant}}}$ is $2\sqrt{z + \text{constant}}$,

therefore

$t_{\mathrm{f}} = \frac{4791}{d^2} \times \frac{V_{\mathrm{C}}}{h_{\mathrm{c}}}\left(\sqrt{z_{\mathrm{c}} - z_{\mathrm{d}}} - \sqrt{z_{\mathrm{b}} - z_{\mathrm{d}}}\right) = \frac{4791}{d^2} \times \frac{V_{\mathrm{C}}}{h_{\mathrm{c}}}\left(\sqrt{h_{\mathrm{c}} + \Delta z_1} - \sqrt{\Delta z_1}\right)$ with $\Delta z_1 = z_{\mathrm{b}} - z_{\mathrm{d}}$ and, to sum up

Drain case 2 full drain no head loss $t_{\mathrm{f2}} = \frac{4791}{d^2} \times \frac{V_{\mathrm{C}}}{h_{\mathrm{c}}}\left(\sqrt{h_{\mathrm{c}} + \Delta z_1} - \sqrt{\Delta z_1}\right)$ and

Partial drain no head loss $t_{\mathrm{p2}} = \frac{4791}{d^2} \times \frac{V_C}{h_c}\left(\sqrt{h_c + \Delta z_1} - \sqrt{\Delta z_1 + 0,1}\right)$

DRAIN CASE 3 — Drainage with a vertical pipe ending below waterline

The Bernoulli equation is applied at point z (between point c and b) and outlet point f, which is below W_{L}, and using, for simplification $z_{\mathrm{b}} - z_{\mathrm{f}} = \Delta z_2 + \Delta z_3$ with $z_{\mathrm{b}} - z_{\mathrm{e}} = \Delta z_2$ and $z_{\mathrm{e}} - z_{\mathrm{f}} = \Delta z_3$

$\frac{u^2}{2} + \frac{p_{\mathrm{atm}}}{\rho} + gz = \frac{u_{\mathrm{f}}^2}{2} + \frac{p_{\mathrm{f}}}{\rho} + g\left(h_{\mathrm{c}} - \Delta z_2 - \Delta z_3\right)$ or $\frac{u_{\mathrm{f}}^2}{2} = \Delta z_3 + g\left(z - \left(h_{\mathrm{c}} - \Delta z_2 - \Delta z_3\right)\right)$

with $p_{\mathrm{f}} = p_{\mathrm{atm}} + \rho \Delta z_3$ and $u \approx 0$ then

$$u_{\mathrm{f}} = \sqrt{2\left[g\left(z - \left(h_{\mathrm{c}} - \Delta z_2 - \Delta z_3\right)\right) + \Delta z_3\right]} = \sqrt{2g\left(z - \left(h_{\mathrm{c}} - \Delta z_2 - \Delta z_3\left(1 - \frac{1}{g}\right)\right)\right)} = \sqrt{2g\left(z - h_{\mathrm{c}} + \Delta z_2 + 0,9\Delta z_3\right)}$$

and

Drain case 3 full drain no head loss $t_{\mathrm{f3}} = \frac{4791}{d^2} \times \frac{V_C}{h_c}\left(\sqrt{h_c + \Delta z_2 + 0,9\Delta z_3} - \sqrt{\Delta z_2 + 0,9\Delta z_3}\right)$ and

Drain case 3 partial drain no head loss $t_{\mathrm{p3}} = \frac{4791}{d^2} \times \frac{V_C}{h_c}\left(\sqrt{h_c + \Delta z_2 + 0,9\Delta z_3} - \sqrt{\Delta z_2 + 0,9\Delta z_3 + 0,1}\right)$

B.2 Calculation with "real" fluids and head losses — General

Applying the Bernoulli equation for "real" fluids between water level in the tank and outlet of the drain system and along the same line of flow (with head losses but still no energy input/output):

